

MAD SCIENTIST' CONFERENCE

VISUALIZING MULTI DOMAIN BATTLE

2030 - 2050

25-26 JULY 2017



Co-sponsored by:

**U.S. Army
Training and
Doctrine Command**

**Georgetown University
Center for Security Studies**

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On future battlefields, the United States will no longer have unquestioned superiority over its adversaries, who because of the development and convergence of advanced technologies and the creation and adoption of hybrid strategies, will gain comparative advantages and perhaps even overmatch capabilities against us. Highly advanced adversaries, near-peer competitors, and even non-state groups and empowered individuals will have invested and will continue to invest in disruptive technologies and methods of warfare that will degrade, disrupt, or deny our greatest strength—our ability to operate jointly and seamlessly across the land, sea, air, cyber, and space domains

The U.S. Army, in concert with its sister services, is exploring **Multi-Domain Battle** – warfare, engagement, and coordination across all domains – as its blueprint to fight and win in an operational environment where our adversaries contest or even deny some or all domains. Multi-Domain Battle will allow Army and Joint forces to create windows of opportunity against an adversary that will change denied domains into contested arenas or contested arenas into opportunities to deliver critical effects against enemy targets and maneuver to gain significant advantage. In addition to confronting adversaries that are contesting the physical domains, the U.S. military also will have to compete across the electromagnetic spectrum (EMS), the information environment, and within the cognitive dimension of warfare.

To explore the challenges and opportunities presented by multi-domain battle in the 2030-2050 timeframe, the United States Army Training and Doctrine Command (TRADOC) co-hosted the Mad Scientist: Visualizing Multi-Domain Battle 2030 – 2050 conference with Georgetown University's Center for Strategic Studies on 25 – 26 July in Washington, DC. The conference debuted the new TRADOC G-2 Deep futures assessment – "The Operational Environment and the Changing Character of Future Warfare" – and presented and published 16 papers on multi-domain topics such as networks, Soldier enhancement, medical support, and smart cities/megacities. Conference attendees included representatives from private industry, academia, and a host of government and military organizations including Congressional staffers, the Office of the Secretary of Defense, Joint Staff, Army Staff, Secret Service, Federal Bureau of Investigation, Department of Homeland Security, and other Intelligence Community elements. Keynote speakers discussed a number of topics ranging from ethics in autonomous weapons systems and robotics to neurotechnology in national security and defense. Additionally, several hundred other participants from the United States and 17 other countries viewed the conference via live streaming on the Internet. Many of these viewers participated in a crowdsourcing exercise that will support future TRADOC G-2 analysis. All of the input was mined for useful ideas that will help us understand possible outcomes and developments that could affect our understanding of the future Operational Environment.

The conference generated the following key findings:

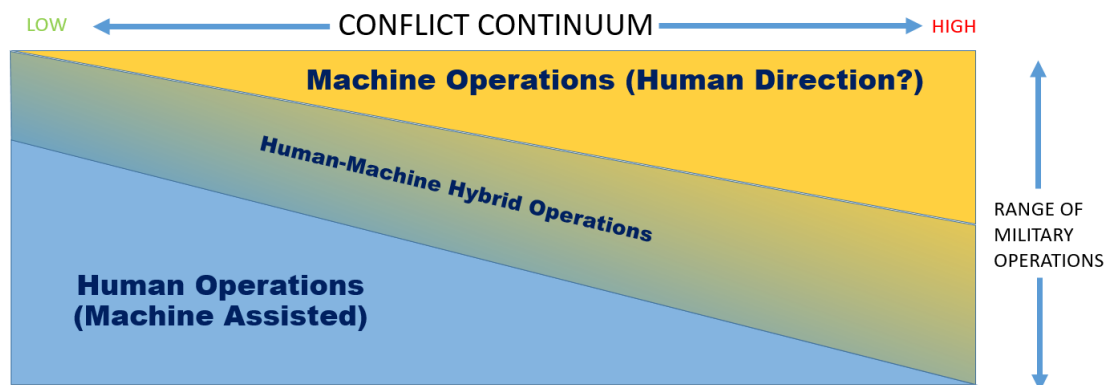
- The role of the human on the future battlefield will be redefined; human military operations first will be machine-assisted (i.e., fully integrated man-machine), and then transition to machine operations that will be human-assisted.
- The Army of the future will need Smart Installations that enable strategic support areas critical to MDB and are capable of operating in and around smart cities that enhance human engagement, but create new challenges in terms of the environment.
- To operate on the future battlefield, the Army may need to radically change the construct and composition of its various units.
- The Army will need peer-to peer-communications capabilities that take advantage of a new era of machine-to-machine (M2M) or device-to-device (D2D) communications to enable dispersed formations and multi-domain swarming of unmanned systems.
- Due to advances and a renewed focus on neuroscience, the brain may be the next battlespace. Important ethical and moral questions must be addressed and potential roadblocks in this area must still be overcome.
- Super-empowered individuals will have a significant impact on what constitutes acts of war, rules of engagement, and national security; Conflict may lack defined geographies, and nation-states may become less relevant or even become extinct. Alternative social ordering along ideological beliefs, regional interests, or even singular issues may develop.
- The Army will need to address ethical dilemmas stemming from an ever-increasing convergence of Artificial Intelligence and smart technologies in battlefield systems and with individual soldiers.

An analysis of the presentations, the call for paper submissions, and the crowdsourcing exercise conducted with our virtual participants will help TRADOC understand what Multi-Domain Battle (MDB) means to the Army, its joint and interagency partners and allies, as well as define what the future force will need to contend, win, and thrive in the future Operational Environment.

The Changing Role of the Human on the Battlefield

Over the next two decades, the advancement and widespread use of unmanned, robotic, semi-autonomous, and autonomous weapons, platforms, and even combatants will dramatically change the role of the human on the battlefield of 2030 and beyond. These systems will be used to supplement or supplant humans in both support and combat roles that are considered dull, dirty, or dangerous, while certain adversaries could even use them to undertake operations that are morally, legally, or ethically questionable. Additionally, artificial intelligence and autonomy will be essential to leadership and commanders by assisting in time-critical decision-making, employment of forces, and authorization and ordering of lethal force. While the nature of warfare will remain intrinsically human as long as its aim is the imposition of will over an adversary, the character of warfare will change as the tools used to execute warfare become increasingly less human. Is the Soldier of the future a hyper-enhanced fighter with abilities beyond innate human capabilities, a force manager of unmanned and autonomous/semi-autonomous systems, or an amalgamation of the two?

The rise of artificial intelligence, robotics, and autonomy on the battlefield is analogous to the advent of longbow, gunpowder, and mechanization that precipitated previous changes in the character of warfare. When mass produced rifles and the conical bullet entered the battlefield around the time of the Civil War, the army was still executing massed formations. This implementation made little sense, and maneuver warfare would have provided a great advantage over massed formations. However, while the technology best served by maneuver warfare existed, the supporting technologies to provide the command and control of these large formations (smokeless gunpowder, radios) and new doctrine to implement it did not.¹ The Army is on the precipice of a similar event, where new and novel technology will change the character of war, but only if doctrine and supporting technology keep pace.



¹ Mr. Mathison Hall, "Patrolling in the Infosphere" (speech, Washington D.C., July 25, 2017)

As Artificial Intelligence matures and machines on the battlefield become more pervasive, the future U.S. Soldier will be equipped to offload an increasing number of responsibilities normally reserved for a human. This will range from the obvious mundane and repetitive tasks, to ones that require accuracy and speed that only a machine can deliver. This will also include tasks that are inherently dangerous or life threatening. As the intensity of conflict increases, machines will occupy a greater portion of the range of military operations and human occupation will diminish. This is not to say wars will no longer be fought by humans, rather, it will mean that the **role of the human on the battlefield will need to be redefined**. In the context of the range of military operations, in the 2030-2050 timeframe, human operations will be machine-assisted (i.e., fully integrated man-machine), then move on to machine operations that will be human-assisted. Certain operations, especially those on the low-intensity spectrum, will remain better served with machine-assisted humans; conversely, high-intensity conflict² operations will be fought and occupied largely with robotic systems with the potential for human intervention in a best case scenario (man-on-the-loop).

Smart Cities and Smart Installations: Challenges and Opportunities

The Army of the future will need Smart Installations that will enable strategic support areas critical to MDB and also be capable of operating in and around and taking advantage of the capabilities inherent in a smart city. There are 156 installations that serve as the initial platform of maneuver for Army readiness. Due to increasing connectivity of military bases and the Soldiers, Airmen, Marines, and Sailors, and Civilians who live and work on them to the Internet of Things, DoD and Army installations will not be the sanctuaries they once were. A myriad of emerging threat vectors from social media, cyber-attacks, information operations, and even new generation warfare change the dynamic of how these installations can and should be viewed. Suddenly, service members' children's social media accounts become Order of Battle material for adversaries.³ The readiness processes that take place at home stations are susceptible to disruption and degradation. In the eyes of the enemy, military bases in the homeland and abroad are targeted strategic support areas and a part of the battlefield. Even today, unmanned combat systems can be controlled from home installations — a trend that only will increase in the future.⁴ Conversely, technological integration and advancement of future bases — artificial intelligence, big data, Internet of Things, power generation — also will present tremendous opportunities in areas such as manufacturing, power grids, maintenance, expeditionary capability, and quality of life.⁵

² Ibid

³ Mr. Richard G. Kidd IV, "Smart Installations Supporting the Future Force" (speech, Washington D.C., July 25, 2017)

⁴ Ibid

⁵ Mr. Michael Assante, "IoT, Automation, Autonomy, and Megacities 2025" (speech, Washington D.C., July 25, 2017)

Dense urban areas of the future will become increasingly "smart" over the next two to three decades as they incorporate more Internet of Things devices, functions, and competencies.⁶ Many cities, today and in the future, are implementing technologies in order to keep up with growing demand and decreasing revenue and capability; it is a "have to" scenario rather than "nice to have".

Military facilities and installations of the future will undoubtedly be influenced by the evolution of smart cities and suburbs internationally. The primary challenges of future smart military installations for planners, builders, and commanders will be:

- Incorporating emerging technologies and trends to scale
- Securing those technologies from, or at least mitigating, external cyber disruption and insider threats
- Matching military standards to a wide variety of national and international standards in software, measurement, and energy input/output.

Organization and Force Structure Transformations in the Future

Chief of Staff of the Army, General Mark Milley, in 2016 asked if the Army of the future would have divisions and brigades, or whether it would utilize small, elite Special Forces-like units with operational and strategic level capabilities. At the U.S. Army Annual Meeting and Exposition, General Milley said, "I suspect that the organizations and weapons and doctrines of land armies, between 2025 and 2050, in that quarter-century period of time, will be fundamentally different than what we see today".⁷ **There is a need to change, perhaps radically, some of our organizational unit designs that will allow the Army to operate on the battlefield of the future, which will be dispersed and dangerous across all domains.**

To mitigate and disrupt the threat from state and non-state actors with drastically improved reconnaissance – persistent ISR, electronic detection capabilities, and a saturation of sensors – and extremely lethal strike capabilities – thermobarics, penetrators, dual warheads, hypersonic weapons, long-range artillery, strike and interdiction aircraft – the U.S. Army must consider how to assemble and combine advanced capabilities into technologically-superior land units able to attack and destroy larger enemy units, maneuver over the land domain, and seize and hold terrain in support of these missions. Additionally, these forces must have organic, or at least more readily available, cyber, space, and information warfare capabilities.

The need for these land forces to operate in and across multiple domains prompted General Milley to order the creation of an experimental combat unit known as the Multi-Domain Task Force. The Army recognizes that future combat units will have to be moderately self-sustaining, highly lethal, very fast, and very difficult to pin down on a

⁶ Ms. Grace Simrall, "Sensors on Everything" (speech, Washington D.C., July 25, 2017)

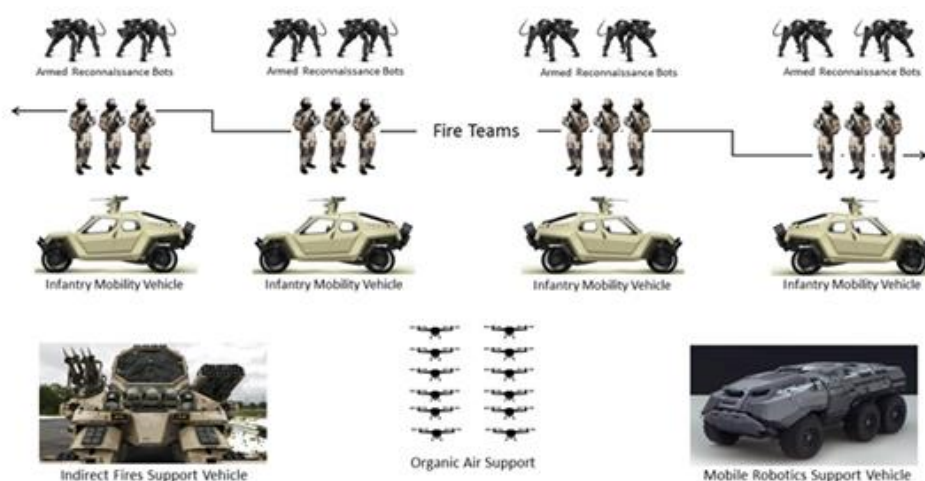
⁷ Lopez, C. Todd. "Milley: Army on Cusp of Profound, Fundamental Change." U.S. Army. October 16, 2016. Accessed September 12, 2017. <https://www.army.mil/article/176231>.

battlefield; current Army force structure does not provide units that can maneuver and operate in this vein. The Multi-Domain Task Force will be the test bed for a concept of operations and force structure that moves beyond just countering adversarial anti-access and area denial (A2/AD) capabilities and will incorporate larger joint efforts for maneuver and combat operations in the future.⁸

Beyond the challenges and opportunities for operational forces more equivalent to today's brigade combat teams, there is growing concern over the loss of technological and mobility overmatches the Army has possessed for the last 15 years at the tactical level. To explore this problem, Mr. Jeff Becker, President and Principal Analyst of Context LLC, spoke at the conference about what the tactical system of the Army might look like in the 2035-2050 timeframe. Mr. Becker's presentation looked at just how lethal, how mobile, how protected and how aware a very small – 12-15 person – unit on the future battlefield might be. He presented a concept of a multi-domain “dagoon” squad, a hyper-enabled combat system composed of numerous future technologies allowing the tactical unit to have multi-domain effects.⁹

Multi-Domain Dagoon Squad Composition

- 12x soldiers, organized in four fire teams
- 4x Infantry Mobility Vehicles (IMVs)
- 8x Armed Reconnaissance Robots (Quadrupedal “Cheetah” variant)
- 1x Autonomous Mobile Robotics Support Vehicle (MRS-V)
- 1x Autonomous Indirect Fires Support Vehicle (IFS-V)



⁸ Freedberg, Sydney J. , Jr., "New Army Unit To Test Tactics: Meet The Multi-Domain Task Force." Breaking Defense. March 21, 2017. Accessed September 13, 2017.

<http://breakingdefense.com/2017/03/new-army-unit-to-test-tactics-meet-the-multi-domain-task-force/>.

⁹ Jeffrey Becker, " How Lethal, Mobile, Protected, and Aware: Exploring the Art of the Possible in Future Infantry Combat " (speech, Washington D.C., July 26, 2017)

The Multi-Domain Dragoon Squad (MDS) provides the Army with a small unit capable of tactical surprise and an enormous capability for close-in lethality. The crux of the MDS is a system-of-systems approach to enabling a small tactical unit with the capability to survive, thrive, and bring about effects across domains throughout the tactical environment in a terrain-agnostic way. This approach is achieved through multiple technological implementations:

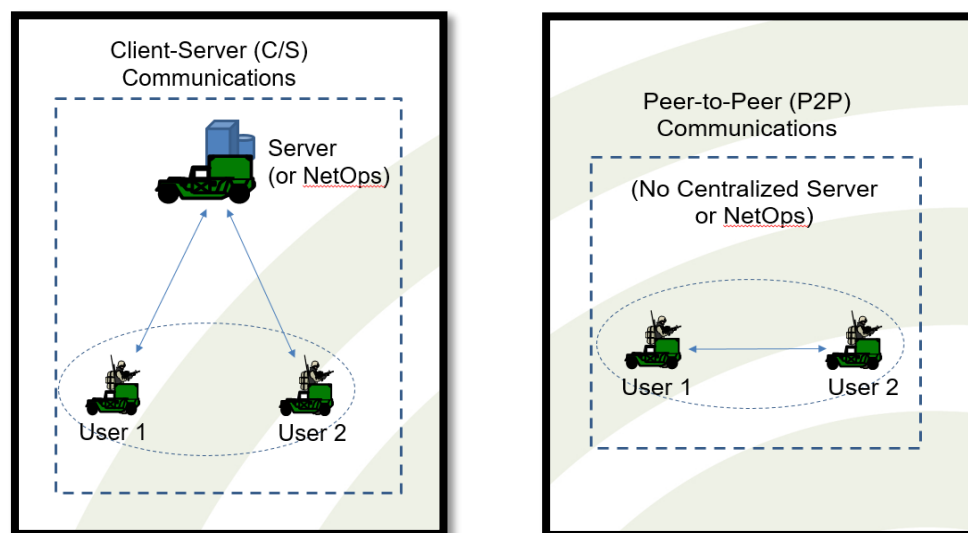
- Equipping of soldiers with soft “exosuits” to increase their strength and endurance allowing for heavier and more capable individual weaponry and the ability to sustain peak performance
- Lightweight helmet-mounted displays providing augmented and virtual reality images based on feeds from sensors – including cyber and electromagnetic environments to reach new levels of close-in situational awareness
- Metamaterials allowing lower profile, higher bandwidth antennas integral to the soldier suit as well as the vehicles and robots
- Modernized assault weapons including guided rounds, increasing the probability of a hit
- Lightweight (4500 lbs.) Infantry Mobility Vehicles (IMVs) capable of semi-autonomy, autonomy, or remote-control as well as the ability to provide covering fire with a robotic turret and precision indirect fires weapons
- Sensor system and associated AI capable of detecting, locating, classifying and prioritizing multiple targets, while providing early warning to fire team
- Eight armed reconnaissance robots able to move over ground at speeds in excess of 40-50 miles per hour; capable of traversing complex terrain quickly and closing with areas of interest at high speed; potential for lethal capability
- Short range, low altitude quadcopter drones providing optical and electronic sensing to the unit, providing constant updates to the AR/VR backbone; potential for lethal capability
- Squad Indirect Fires Support Vehicle (SIF-V) providing a range of indirect fires directly to each team¹⁰

The Multi-Domain Dragoon Squad is not the all-encompassing zenith of the MDB concept but rather is a machination of it at the tactical level that could have a ground-up cumulative change effect. **It is impossible for the Army, nor any of its sister services, to completely transform within a decade; however, sweeping organizational experimentation and reconfiguration of existing formations through initiatives such as the Multi-Domain Task Force can lead to such a transformation.**

¹⁰ Ibid

Operating in the cyber domain presents great vulnerabilities to our current communications systems and architecture. **In 2015, over 460 million new pieces of malware were detected across the world.¹¹ Recently, there has been a rise in AI driven cyber-attacks. These AI driven attacks can use machine learning to adapt and evade detection, causing as much damage as possible or collecting as much information as possible. As time goes on, there will be more surfaces for cyber-attacks as more people get connected on multiple devices.**

The Army will have to deal with a cultural shift as the human and cyber networks — now considered two distinct entities — form one single human-cyber network¹². Humans will be connected with other human bodies all over the world and the idea of connecting to a network exclusively through a device will be archaic. The Soldier will have small tattoo-like sensors on several areas of the body, monitoring and communicating with other soldiers, Command and Control Elements, and autonomous counterparts. Because these sensors and devices will be pervasive, a Machine to Machine (M2M) or Device to Device (D2D) architecture will be dominant. This type of information communications architecture will be primarily peer to peer. This is a fundamental deviation of the classical client-server (C/S) communications¹³. Currently, our devices operate on a network that calls back to a central server (client-server relationship). If communications to the server are disrupted or denied, the entire system loses connectivity. Using a P2P architecture, one can connect to an entity to communicate directly to it or use it as a node to communicate to other devices connected to that node. If that node goes down, or is denied, one can connect to any other available node in the area. In 2050, the Army must use a hybrid system consisting of P2P and C/S.



¹¹ ISTR: Internet Security Threat Report, vol. 21, April 2016.

¹² Dr. Radhika Roy, "Commanding in Multi-Domain Formations: Vision 2050 Warfighter Cyber-Security, Command and Control Architecture" (speech, Washington, D.C., July 26, 2017)

¹³ Ibid

This P2P architecture will be imperative to UAV swarming. Swarming requires each entity to be aware of and anticipate the moves of the other entities in the swarm. That means that each entity in the swarm needs to be able to directly communicate with the others. Swarms will be self-organized, and/or collaborative actions of robots with varying degrees of freedom that require P2P communications without fixed infrastructures (i.e. Mobile Ad-Hoc Networks (MANET))¹⁴. The client-server paradigm will be used less often, mainly as back up for process-intensive actions that less powerful devices can off-load.

Because of the sheer speed and frequency of cyber-attacks, humans will be overmatched. However, with algorithms, machine learning, and natural language processing, cyber-attacks can be prevented, detected, and repaired at machine speed without reliance on humans. Machine learning will allow them to adapt to newer and more sophisticated attacks, and the decentralized nature of P2P architecture will enable each machine to work independently without needing to wait for other entities.

Current network architectures and paradigms will not sufficiently support the Army of 2050. The centralized nature of a client-server architecture is not fast enough or dynamic enough to keep up with the pace of AI enabled cyber-attacks. The Army must move to a mostly P2P network allowing individual entities to act, process, and communicate independently, serve as nodes, and take advantage of swarming capabilities. In the multi-domain battle of 2050, this new architecture will allow the Army to better and more efficiently communicate, reduce points of failure, and minimize cyber-attack surfaces.

The Battle of the Brain

The future battlespace will include not only the land, sea, air, cyber, and space domains but also the brain. **Attacks and manipulation on Soldiers' and noncombatants' brains represent a significant threat, challenge, and opportunity in neurotechnology.** The human brain will be a prominent facet of Multi-Domain Battle.

At the conference, Dr. James Giordano, Chief of the Neuroethics Program at Georgetown University, explained how neuroscience has made huge leaps by using technology to study and understand how nerves, nervous systems, and brains are structured and function. Neuroscience and technology (NeuroS/T) puts the brain at our fingertips, enabling us to understand it better. This knowledge enables new and exciting potential to improve our memories, expand our cognitive abilities, and even repair damaged brains; conversely the same knowledge also presents new vulnerabilities that technologies can target.¹⁵

¹⁴ Ibid

¹⁵ Dr. James Giordano, " Neurotechnology in National Security and Defense" (speech, Washington D.C., July 26, 2017)

For operators/warfighters, there are a number of “weapons” of choice such as: neuro-enablement (i.e., advanced neuro-psychopharmacologies); computational brain-machine interfaces; closed-loop brain stimulation approaches; and neuro-sensory augmentation devices. While they are not traditional weapons like guns, missiles, or blades, these technologies will make warfighters more lethal, aware, resilient, and integrated with the combat systems they utilize.

Novelty neuroweapons give adversaries, and perhaps the United States, the capability to kill, disrupt, degrade, damage, and even hack human brains to influence populations, bring about confusion and panic, and disrupt an enemy’s government and society often without mass casualties. Neuroweapons are “Weapons of Mass Disruption” that may characterize major segments of warfare in the future.

The host of capabilities and possibilities gained from neuroweapons and NeuroS/T bring a multitude of ethical and moral considerations and conundrums along with them. Does affecting someone’s brain purposely, even temporarily, violate ethical codes, treaties, conventions, and international norms followed by the United States military? Does current policy adequately address the roles and responsibilities of commanders and individual soldiers in their employment of such weapons? If you influence or impact human brains without causing death or physical pain, is this still an act of war or belligerence? At this point there are more questions than answers. **What is clear is that the United States must explore not only what is possible, but what is justified, appropriate, and legally possible in the Battle of the Brain.**

NeuroS/T provides a number of novel neuroweapons:

- **Pharmaceuticals and organic neurotoxins (i.e., ultra-low dose/high specify agents for use in targeting diplomatic/local culture “hearts and minds” scenarios)**
- **High morbidity neuro-microbiologic agents (i.e., neuro-microbials with high neuro-psychiatric symptom clusters for public panic/public health disintegrative effects)**
- **Gene-edited microbiologicals with novel morbidity/mortality profiles**
- **Nano-neuroparticulate agents: high central nervous system (CNS) aggregation lead/carbon-silicate nanofibers (network disrupters); neurovascular hemorrhagic agents (for in-close and population use as “stroke epidemic” induction agents).**

Super-empowered individuals will become more common due to the range of disruptive technologies — smart phones as multi-spectral sensors and

Characteristics of Super Empowered Individuals

- **Highly connected and able to reach far beyond their geographic location.**
- **Access to powerful, low-cost commercial technology.**
- **Often more difficult to trace or attribute responsibility to actions.**
- **Not beholden to nation-state policies, ethics, or international law.**
- **Varying motivations (political, ideological, economic, and monetary)**
- **Often unpredictable, may not operate or execute like a traditional rational actor**

jammers; commercial UAVs as precision guided munitions, high powered computers with malware/infoware “weapons” — available to them. This has been evidenced by the rise in global malware attacks, hacking of vehicles that operate with computers, and information operation campaigns through social media that have influenced policy, disrupted everyday life, and increased global security costs and concerns; these cyber capabilities coupled with widespread proliferation of deadly technologies and the tactics,

techniques, and procedures associated with them, gives **super-empowered individuals the capability to disrupt, degrade, and deny Army forces across multiple domains. An individual armed with a high-powered computer and proficient coding, programming, and/or hacking capabilities could induce as much damage as an entire battalion of belligerent forces.** Individuals may derive motivation from a cause, monetary incentives, or simply from curiosity.

These national and global security concerns are only worsened by individuals in the future obtaining technologies and techniques that today are primarily limited to intelligence agencies.¹⁶ Meanwhile, the ability of states to counter or even deter the malicious use of available technologies is unclear. The capabilities of super-empowered individuals to deliver effects previously limited to state actors brings about questions as to what constitutes an act of war in the future. What are the boundaries in a conflict between states and individuals? There is a severe lack of modern policy addressing these issues. Additionally, for the Army there is little doctrine ascribed to surveilling, targeting, and engaging super-empowered individuals outside of current counterterrorism policy and regulations. The future operational environment and the Army’s way of war will be heavily impacted by super-empowered individuals; the Army will have to pursue unique avenues of approach to mitigate this growing threat.

¹⁶ Dr. David Bray, " Blurred Lines and Super-Empowered Individuals: *Is National Security Still Possible in 2040?*" (speech, Washington D.C., July 25, 2017)

With advances in Artificial Intelligence, human enhancement, and autonomous weapons, the Army must be prepared to enter new ethical territory and make difficult decisions about the creation and employment of cutting edge technology. The Army holds itself to a high ethical standard, and while technology may be able to lessen the burden of some military tasks, it may come at an ethical cost. Updating guidance, policy, and law must be considered well before these enabling technologies become common and employed on the battlefield. What's more, many of these ethical dilemmas and questions lack definite answers.

Human enhancement will undoubtedly afford the Soldier a litany of increased capabilities on the battlefield. Augmenting a human with embedded communication technology, sensors, and muscular-skeletal support platforms will allow the Soldier to offload many physical, mundane, or repetitive tasks but will also continue to blur the line between human and machine. Some of the many ethical/legal questions this poses, are at what point does a Soldier become more machine than human, and how will that Soldier be treated and recognized by law? At what point does a person lose their legal personhood? If a person's nervous system is intact, but other organs and systems are replaced by machines, is he/she still a person?¹⁷ These questions do not have concrete answers presently, but, more importantly, they do not have policy that even begins to address them. The Army must take these implications seriously and draft policy that addresses these issues now before these technologies become commonplace. Doing so will guide the development and employment of these technologies to ensure they are administered properly and protect Soldiers' rights.

Fully autonomous weapons with no human in the loop will be employed on the battlefield in the near future. Their employment may not necessarily be by the United States, but they will be present on the battlefield by 2050. This presents two distinct dilemmas regarding this technology. The first dilemma is determining responsibility when an autonomous weapon does not act in a manner consistent with our expectations. For a traditional weapon, the decision to fire always comes back to a human counterpart. For an autonomous weapon, that may not be the case. Does that mean that the responsibility lies with the human who programmed the machine?¹⁸ Should we treat the programmer the same as we treat the human who physically pulled the trigger? Current U.S. policy doesn't allow for a weapon to be fired without a human in the loop. As such, this alleviates the responsibility problem and places it on the human. However, is this the best use of automated systems and, more importantly, will our adversaries adhere to this same policy? It's almost assured that the answer to both questions is no. There is little reason to believe that our adversaries will employ the same high level of ethics as the Army. This means Soldiers will likely encounter autonomous weapons that can target, slew, and fire on their own on the future battlefield. The human Soldier facing them will be slower, less accurate, and therefore

¹⁷ Linda MacDonald Glenn, "Panel: Ethics and the Future of War" (speech, Washington D.C., July 25, 2017)

¹⁸ Jimmy Zhang, "Panel: Ethics and the Future of War" (speech, Washington D.C., July 25, 2017)

less lethal. So the Army is at a crossroads where it must decide if employing automated weapons aligns with its ethical principles or if they will be compromised by doing so. It must also be prepared to deal with a future battlefield where it is at a distinct disadvantage as its adversaries can fire with speed and accuracy unmatched by humans. Policy must address these dilemmas and discussion must be framed in a battlefield where autonomous weapons operating at machine speed are the norm.

Technology is going to change the character of future war. It will change the way we employ our weapons, train our soldiers, and make decisions. These changes are inevitable, but require careful planning and a dedicated review of our ethical posture.

Difficult decisions will have to be made about the constitution of a human versus a machine and where one ends and the other begins. Policy will have to be created to guide us on how much decision making power we grant to non-human entities. The longer we wait to address these issues, the farther behind our adversaries we fall and the more disadvantaged we become.

Conclusion

The 2017 Mad Scientist conference on Multi-Domain Battle covered a range of important topics dealing with warfare in 2050. The ultimate goal was to help the Army understand the possible outcomes and developments that could affect our understanding of the future Operational Environment. Through the collective work of the conference speakers, the call for papers, and the crowd-sourcing exercise, Mad Scientist was able to determine key findings that will define what the future force will need to contend, win, and thrive within a Multi-Domain battlefield of the future Operational Environment.

Future American land forces will find themselves in an ultra-competitive and contested hyper-active battlespace with ever-growing complexity where timetables become truncated, tactical actions have instantaneous strategic implications, and Soldiers and their leadership are constantly beset with moral, ethical, and situational ambiguities.

The Army of 2050 will need to:

- Redefine the role of the Soldier as machines become more prevalent
- Augment Army installations with smart infrastructure
- Change organizational unit designs to be more dispersed across all domains
- Update and upgrade our networks to a predominantly Peer-to-Peer architecture
- Prepare to use the brain as a battlespace
- Understand the changing geopolitical atmosphere where nation states may not look the same in 2050 and super-empowered individuals will test the limits of acts of war
- Develop policies to address new dilemmas and questions that the new aspects of war bring

Many, if not all, of these findings do not have clear and defined answers or solutions, but through this conference, they have a clear starting point and path forward. What has been evident throughout is that the Army cannot afford to employ a wait and see approach. Delaying the discussion now will only serve to increase any disadvantage we may have in the future. If we wait to address these issues until our adversary presents them on the battlefield, then it will already be too late.

Agenda Day 1: Tuesday, 25 July 2017

0800-0845	Registration
0845-0850	Admin Remarks: Lee Grubbs, Director, Mad Scientist Initiative, TRADOC
0850-0900	Welcoming Remarks: Mr. David Maxwell, Associate Director of the Center for Security Studies, Georgetown University
0900-1000	Multi-Domain Battle: General David Perkins, Commanding General, TRADOC
1000-1030	Science Fiction Contest Winner: Patrolling in the Infosphere: Mr. Mathison Hall, Senior Analyst, Johns Hopkins University Applied Physics Lab
1030-1045	Break
1045-1115	Blurred Lines and Super-Empowered Individuals: <i>Is National Security Still Possible in 2040?</i> Dr. David Bray, Director, Office of Ventures and Innovation, NGA
1115-1200	Panel: Visualizing the Future of War 2030 – 2050: Dr. David Bray, Office of Ventures and Innovation, NGA Mr. James “Hondo” Geurts, Acquisition Executive, USSOCOM Mr. Mathison Hall, Johns Hopkins University Applied Physics Lab Dr. Anthony Vinci, Director Plans and Programs, NGA
1200-1300	Lunch (provided on site), Senior Officer Working Lunch; Mr. Geurts: Rapid Acquisition and Innovation in Support of SOCOM
1300-1315	Smart Installations Supporting the Future Force: Mr. Richard G. Kidd IV, Deputy Assistant Secretary of the Army (IE&E), Strategic Integration
1315-1415	Smart Cities and the Future: Dr. Sokwoo Rhee, Associate Director of Cyber-Physical Systems Program, National Institute of Standards and Technology
1415-1430	Break
1430-1530	IoT, Automation, Autonomy, and Megacities 2025: Mr. Michael Assante, Director Industrials & Infrastructure, CSIS
1530-1630	Sensors on Everything: Ms. Grace Simrall, Chief of Civic Innovation for the City of Louisville, KY
1630-1640	Closing Remarks: MG Robert Dyess, Deputy Director, ARCIC
1700-2000	No Host Social

Agenda Day 2: Wednesday, 26 July 2017

- 0845-0900** **Welcome Remarks:** LTG Sean MacFarland, Deputy Commanding General, TRADOC
- 0900-1000** **How Lethal, Mobile, Protected, and Aware: Exploring the Art of the Possible in Future Infantry Combat:** Mr. Jeffrey Becker, President and Principal Analyst, Context LLC
- 1000-1100** **Commanding in Multi-Domain Formations: Vision 2050 Warfighter Cyber-Security, Command, and Control Architecture:** Mr. Radhika Roy, Electronics Engineer, U.S. Army CERDEC
- 1100-1200** **Neurotechnology in National Security and Defense:** Dr. James Giordano, Chief of Neuroethics Program, Georgetown University
- 1200-1300** **Lunch (provided on site), *Optional Working Lunch*; Mr. Steve Banach: From 9/11 to London: The Need for Virtual Battle Space Maneuver Doctrine**
- 1300-1415** **Panel: Ethics and the Future of War:**
Moderator: LTG (Ret) Jim Dubik
Panel Members: Jimmy Zhang and Rachael Greene, Georgetown University Strategic Studies Program Students
Dr. Jesse Kirkpatrick, Institute for Philosophy and Public Policy, George Mason University
Professor Linda MacDonald Glenn, Institute for Ethics and Emerging Technologies, California State University, Monterey Bay
- 1415-1515** **AI and Autonomy in Future War:** Dr. Jesse Kirkpatrick, Institute for Philosophy and Public Policy, George Mason University
- 1515-1615** **Ethics and Law around the Co-Evolution of Humans and AI:** Professor Linda MacDonald Glenn, Institute for Ethics and Emerging Technologies, California State University, Monterey Bay
- 1615-1630** **Closing Remarks:** Mr. Thomas Greco, TRADOC DCS, G-2

All of the presentations can be viewed on YouTube: <https://youtu.be/Xcq-Ok0mO8A>

TRADOC Mad Scientist/Georgetown University Crowd Sourcing Exercise Report

As part of the Georgetown Conference, the TRADOC Mad Scientist Initiative conducted a crowd-sourcing exercise using Twitter. Crowdsourcing is a futuring tool the Mad Scientist team uses to maximize engagement in the spaces where people feel comfortable contributing. The objective was to identify new ideas or more effective ways to describe emerging technologies and concepts.

The exercise challenged contributors to describe an attribute of the future of war or Multi-Domain Battle. There were several hundred #MultiDomainBattle tweets submitted during the week of 24 – 28 July 2017. These submissions came from many different communities including government, industry, academia, and international. The top twenty-five tweets are listed below with the top three annotated in bold text. Additionally, there were two power tweeters @Tyler_Sweatt and @EdGSantosJr. We appreciate their engagement and the many great ideas the contributors added to this exercise.

There were five key themes across many of the contributions. These themes build on ideas described in the TRADOC G2's "Operational Environment and the Changing Character of Future Warfare" assessment and highlight many of the assessments provided by presenters at the Georgetown Conference. Key Themes:

1) While humans are still a central part of the future battlefield, who they lead and how they train and fight will be different. Entangled trends of demographics, robotics, autonomy, artificial intelligence, and human machine interface mean a changing identity of Soldiers. Emerging AR/VR will open new possibilities for building readiness and change the roles of installations from training spaces to training and operational spaces. Mixed formations of robotics and Soldiers could challenge cohesion and trust.

2) Historically, emerging technologies of military importance originated in the government domain. Contributors highlighted the changing dynamic of democratization of technologies and low technology open source capabilities to counter states. The exercise highlighted technologies such as drones, artificial intelligence, and basic bio-hacking methodologies as the current and next set of challenges.

3) The cognitive dimension is an important aspect of warfare and contributors proclaimed an increasing role with the trustworthiness of information always in question, the virtual and digital space under persistent attack, and the brain space becoming an ever increasing part of the battlefield. One author claimed what the U.S. Army considers as phase one and two could be the main battle area and the war ends before we recognize we are under attack.

4) Multi-Domain battle will start to redefine speed on the future battlefield. The same way that mechanization and jet power changed the battlefield framework, artificial intelligence, robotics, and autonomy will define machine speed where the human will be the speed bump. One tweeter described this as a "hypersonic, electrophonic, cybertronic, constant dilemma chronic" battlefield.

5) Multi-domain battle will challenge our perspectives on what is important and where the decisive fight will take place. The Army will need to define a position of advantage which might be an idea vice a geographical location and we might have new battlefields like installations and cities where our most effective allies are hackers and DiYers (Do it Yourselfers).

Leaders and Units

#MultiDomainBattle and the trends driving may change the identity of the military - colocation, uniforms, formations and training will chg. **Author: @Tyler_Sweatt**

If conflict knows no borders and we can leverage AR / VR to train, what is the role of military installations? Are they just targets? #MultiDomainBattle **Author: @Tyler_Sweatt**

Need to rethink the meaning of unit cohesion when members of a #MultiDomainBattle unit can be a mix of local, remote, and robotic/synthetic. Author: @EdGSantosJr

The C/O of #MultiDomainBattle should win Hearts and Minds. Or hack them if needed it...
Author: @EdGSantosJr

Future C/Os in #MultiDomainBattle will need to quickly ID adversary's intent and options available. Quick analysis methods are essential. **Author: @EdGSantosJr**

PLs w big decisions, fast tech->mission creep (drones v. Cyber) new ways 2 attack more fronts 2 fail. The new maneuver warfare #MultiDomainBattle **Author: @cptmrca**

Biggest challenge in #MultiDomainBattle will be building leaders able to operate across all domains high and low tech @ArmyMadSci @TRADOC **Author: Tyler_Sweatt**

Operational Environment and Future War

@ArmyMadSci #MultiDomainBattle. A missing element in MDB is need for Red opposing forces, with open-source low tech counters to high tech. **Author: @seahorse14941**

#MultiDomainBattle strategy must look for underutilized, practical aspects of tech already on hand to gain agility **Author: @GrahamPlaster**

#MultiDomainBattle Part of Orient in any OODA will be how trustworthy is the info assumed to be observed. **Author: @EdGSantosJr**

Future war presents not an enemy but a system of resistance. Who, what are we defending in virtual space? #MultiDomainBattle **Author: @nkhaden**

New YouTube video link. Click or not? Mom? Smiling cats? Malware? Subliminal messages? #MultiDomainBattle weaponizes fear and uncertainty. **Author: @EdGSantosJr**


#MultiDomainBattle might start and end before it is even recognized as a battle. **Author: EdGSantosJr**

War of #MultiDomainBattle begins worldwide much b4 any shot fired. One must attack adversary's plan and defeat it first and foremost. **Author: @EdGSantosJr**

Using neurology to transform intelligence in #MultiDomainBattle - does the brain become a target in future wars? @ArmyMadSci @TRADOC **Author: @Tyler_Sweatt**

Beyond cyber&space: revolution in bio-&neurotech (eg: CRISPR, optogenetics, NEURINT) a "science fact." Wars within body! #MultiDomainBattle **Author: @roennekus**

Multi-Domain Battle Descriptions

 's+Soldiers understand & move @ machine speed thru contested spaces IOT deny EN options n our favor, adapting w/o HQ's= #multidomainbattle **Author: @Chris_Telley**

Speed will be a key attribute #MultiDomainBattle. Fused & timely understanding of threat dimensions & 'threat velocities' will be key. Author: @vpkivimaki

One key of #MultiDomainBattle is to understand the different speeds of a maneuver in each domain to sync it to reach goal/effect. **Author: @EdGSantosJr**

#MultiDomainBattle it's hypersonic, electrophonic, cybertronic, constant dilemma chronic, confuse the enemy and objective? Keep on it! **Author @AlfredCrane**

WaPo Headline: Cyber Command resistant to coordinate with Silicon Valley Militia **Author: @50Cal4n6**

All good for #MultiDomainBattle to require maneuver to "positions of relative advantage", but first step is to understand what advantage is **Author: @John_T_Watts**

#MultiDomainBattle is the Jeet Kune Do of warfare; able to respond to an adversary's attack with multiple possibilities. **Author: @mjsmithmack**

#MultiDomainBattle Sub drop SEALs behind lines, escort cyber that hack local radars, fighter breaches airspace to s/d local OpFor satellite. **Author: EdGSantosJr**

#multidomainbattle cyber fight may rage inside Louisville systems at same time as overseas combat. CyberCommand ready to fight CONUS? **Author: @Mike40245**

U.S. Army TRADOC Mad Scientist Sci-Fi Stories

Executive Summary by Luke Shabro and Allison Winer

In November 2016, the U.S. Army TRADOC Mad Scientist Initiative launched its first Science Fiction Writing Competition, with the topic “Warfare in 2030 to 2050.” This contest sought unconventional thinkers and was open to people from all walks of life. One of the founding ideas inspiring the contest was the notion of ‘Science Fiction as reality.’ Science fiction has been historically predictive of future technologies and ideas. One example is the prevalence of mobile “smart devices” and advanced video communications in popular films and television such as *Star Trek* and *Back to the Future*. These kind of forward-looking ideas and themes help the Army think about and prepare for future challenges and opportunities in conflict. We sought to challenge writers with the opportunity to contribute ideas outside of what the Army is already considering about the future, and they delivered.

We experienced “catastrophic success” with over 150 submissions from authors in 10 different countries (Singapore, Germany, Finland, UK, Russia, Ukraine, USA, Canada, New Zealand, and Australia). This diversity in authors presented us with a wide variety of thoughts and ideas on the future Operational Environment and warfare. Through the art of storytelling, the Army was able to visualize the known, probable, and possible challenges and opportunities that the future holds.

The stories allowed the readers to place themselves in a world where familiar met unfamiliar. This world featured a myriad of future technologies forcing paradigm shifts away from current, conventional thinking. The future world was hyper connected, extremely dynamic, and at times uncertain. Writings portrayed an environment in which humans, and especially Soldiers, were confronted with complex, rapidly-changing situations outside of the known operational environment of today. Despite the variety of the imaginative worlds presented, there were a multitude of technologies and themes that were prevalent. These commonly recurring themes and technologies provided valuable insight into warfare in 2030 to 2050.

Drones: The most commonly featured, spanned across all physical domains: Land, Air, Sea, and even Space. Sizes ranged from micro to the size of conventional aircraft and ships. Drones in the stories were smart, self-healing, self-learning, cognitively connected to users, and used in swarming across all domains, often autonomously.

HUD/ AR/ VR: Military personnel and civilians alike in the stories frequently used heads-up displays (HUDs). These were typically integrated with augmented reality (AR), real-time networked communications, and multiple weapon, vehicle, and intelligence system interfaces. Virtual reality (VR) and AR were critical components in future warfighter training, planning, and decision-making.

Human enhancement: Human performance enhancement and augmentation in many of the stories ranged from known technology such as pill-form stimulants/enhancers to permanent implants and genetic modifications.

Advanced Artificial Intelligence (AI): More advanced and robust than today- self learning, autonomous, and trusted by humans; sometime even sentient. AI was available at the edge of the battlefield to automate a multitude of processes, improve situational understanding, control weaponry and C2 functions, and aid in decision-making.

Advanced Materials: Nanomaterials, cutting-edge synthetics, smart materials, and radical new metals enabled other technologies to exist and advance (i.e. exoskeletons, space craft, and medical).

Through the depiction of the aforementioned technologies and the portrayal of future environments, multiple prominent themes emerged in the Sci-Fi corpus.

Virtually every new technology is connected and intersecting to other new technologies and advances. **Convergence** frequently occurred across numerous technologies. Advances in materials, AI, drones, communications, and human enhancement amplified and drove one another across multiple domains. A major **cultural divide** and gulf in understanding still existed between different populations even with developments in technology (including real-time language translators). While increasingly integrated and advanced systems improved upon each other, the inherent **connectivity and complexity** that resulted presented a number of challenges and opportunities for future forces and populations. The fully enmeshed communications and sensing residing in future systems made the **hiders vs. finders** competition ever more important in future conflict settings. Additionally, the constant battle for and over **information** often meant victory or failure for each side. Due to the snowballing speed of interaction on the battlefield (during and in between high-intensity conflict), a number of the military units in the stories required **smaller units**, with large effects capabilities and more authority, and operated under **flat and dispersed command and control structures**.

The [linked compendium](#) of some of our top science fiction stories gives an enlightening window into the future operational environment and the future of warfare. As one reads this collection of stories, they can almost imagine the look, feel, and sense of what “Warfare in 2030-2050” will be.